Dec. 8, 1959 E. A. HANYSZ ET AL 2,916,694

COATING THICKNESS GAGE

Filed March 2, 1956 3 Sheets-Sheet 1

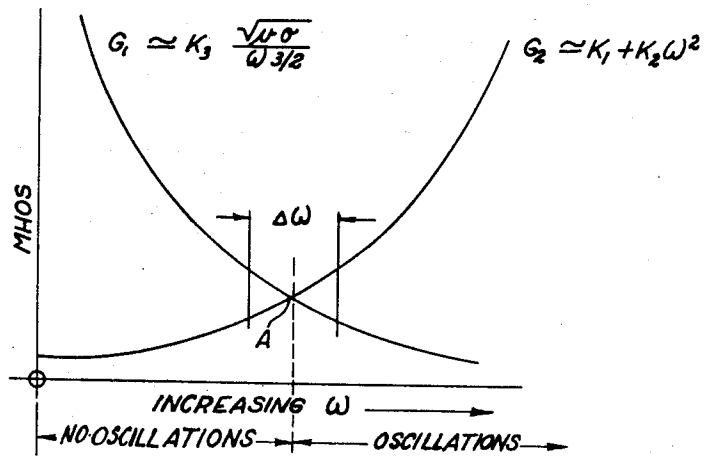


Fig. 1

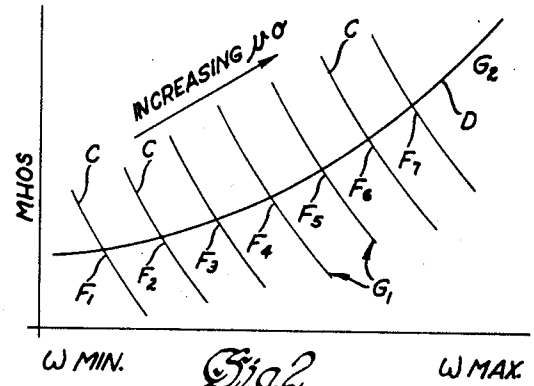


Fig. 2

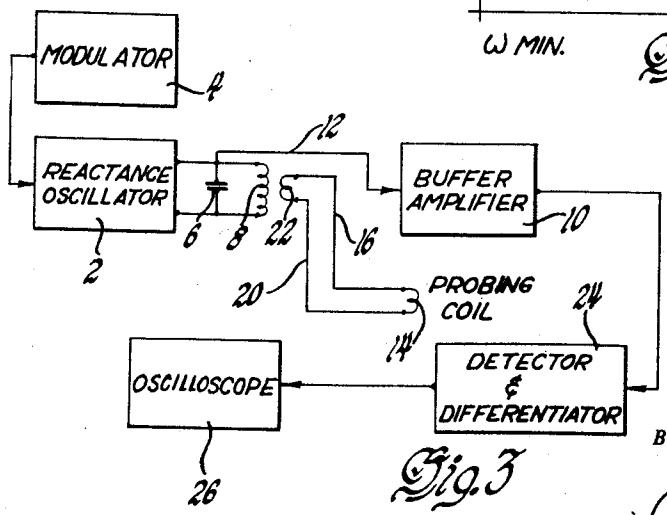


Fig. 3

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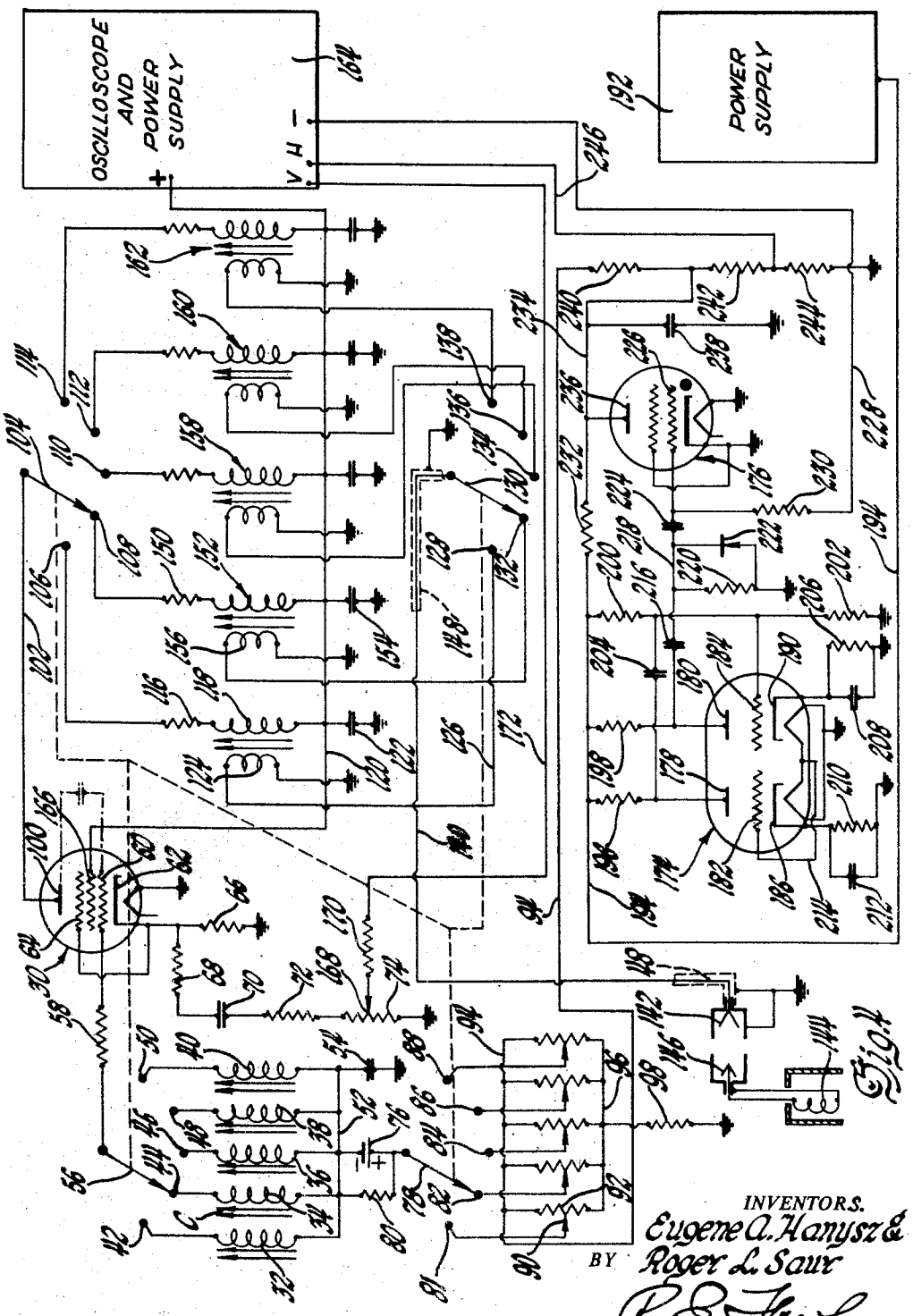


Fig. 4

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COATING THICKNESS GAGE

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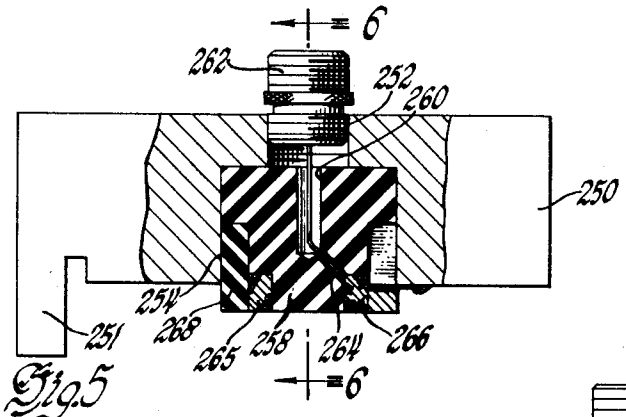


Fig. 5

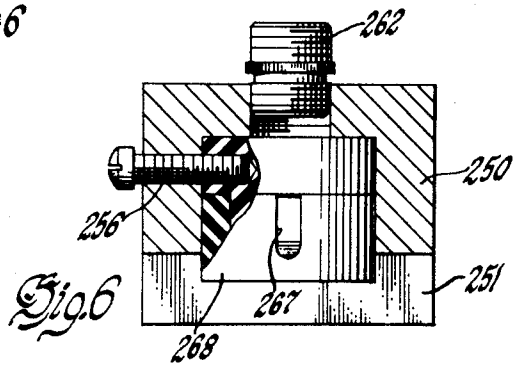


Fig. 6

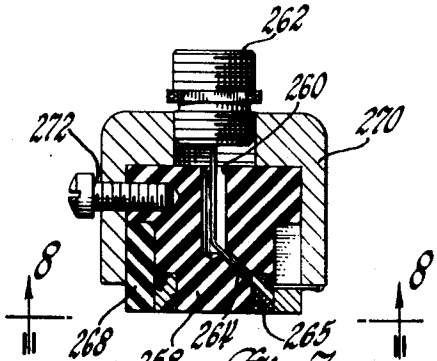


Fig. 7

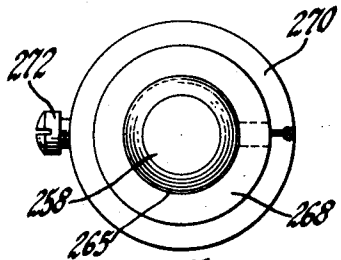


Fig. 8

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United States Patent Office 2,916,694
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2,916,694

COATING THICKNESS GAGE

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Application March 2, 1956, Serial No. 569,063

10 Claims. (Cl. 324—34)

This invention relates to measuring means and more specifically to nondestructive testing means for measuring the thickness of coatings or platings of one material on another.

It is desirable and often necessary to obtain a measurement of the thickness of a coat of paint or a plated metal area to determine whether the part or surface coating meets the specifications set up therefor.

It is therefore an object in making this invention to provide means to gage or measure the thickness of lamina of a composite part.

It is a further object in making this invention to provide nondestructive testing means for measuring the thickness of a coating or plating layer or layers on a base.

It is a still further object in making this invention to provide means for measuring the thickness of a thin layer of one material on a base by utilizing the change in loading on an oscillator-driven inductance coil.

With these and other objects in view which will become apparent as the specification proceeds, our invention will be best understood by reference to the following specification and claims and the illustrations in the accompanying drawings, in which:

Figure 1 is a graph illustrating the theory of the selection of an operating frequency;

Figure 2 is a graph illustrating the effect of varying the total load on the frequency selection for operation;

Figure 3 is a block diagram of a measuring system embodying our invention;

Figure 4 is a circuit diagram of a measuring system embodying our invention, parts being shown in block diagram form;

Figure 5 is a side elevation of a probing coil assembly to be used with the system, parts being broken away and shown in section;

Figure 6 is a sectional view taken on line 6—6 of Figure 5;

Figure 7 is a vertical sectional view taken through a modified form of coil cover shield and support; and

Figure 8 is a bottom view of the shield and support taken on line 8—8 of Figure 7.

The present measuring system is based on the principle that alternating currents induced in a conductive material, "eddy currents" as they are known in the art, penetrate different distances depending on the frequency of the current in accordance with the equation:

$$i=I_0e^{-\sqrt{\pi\mu\sigma f}x}$$

where

x=distance measured from the surface
I_0=current at the surface
i=current at x
e=Naperian base
μ=permeability of the material
σ=conductivity of the material
f=frequency of the alternating current

The depth of penetration is defined by the equation:

$$\delta=\frac{1}{\sqrt{\pi\mu\sigma f}}$$

The higher frequency, the less the current penetration and the more the tendency of the current to flow along the surface of the conductor or conductive area. This is known as the "skin effect." It is also apparent that the depth of penetration is affected by the material of the conductor and it can be shown that if one material is deposited on a second material having a different $\mu\sigma$ product, the depth of current penetration in the composite structure will vary in accordance with the thickness of the deposit. If an inductance coil fed by an alternating current source of power of the proper frequency is placed on a composite part having a plating or coating over a base, currents will be induced in the plating layer and into the base. If, through previous knowledge, the depth of current penetration as a function of frequency is known, an oscillator frequency may be selected which will insure penetration of the entire range of desired plating thicknesses under consideration. The probing coil may then be connected to the output of a tunable oscillator whose range includes the selected frequency and placed upon the plated surface. The oscillator may then be tuned over a particular frequency spectrum from a high frequency to a lower one. The induction of the higher frequency currents into the plating layer will cause less depth of penetration than the lower frequency currents. Hence the loading on the oscillator will gradually increase with decrease in frequency. Either some associated electronic circuits or the oscillator may be made sensitive to such a predetermined load, manifesting the instant that the critical load is exceeded in some manner. For example, the oscillator can be made to change its mode of operation. For different plating thicknesses of the same material combinations, the frequency at which the oscillator mode of operation changes will vary. Hence the means for tuning the frequency can be calibrated to read plating thickness. In order to make this change in load clearly perceptible, one embodiment of this system has been designed so that the oscillator changes from an oscillatory mode to a non-oscillatory condition or vice versa. By reading the tuning dial which may be calibrated in distance, the thickness of the layer under examination may be read.

The frequency band over which the power oscillator should be tunable will vary, depending upon the material upon which the device is to be used. As an example, it has been found that utilizing a band around 750 kc. to measure copper platings of the order of .001 of an inch on steel works satisfactorily. Nickel is a poorer conductor of current than copper, and it was found necessary to utilize a band in the neighborhood of 800 kc. for similar thickness nickel plating on steel. The higher frequency is necessary to limit the penetration in a material of poorer conductivity. Babbitt requires a very high frequency band around 21 mc. signal frequency to measure thicknesses of the order of .001 of an inch. This is because of its very poor conductivity.

The present system is based upon the theory of measuring a fixed load and varying the frequency to determine that frequency at which the fixed load occurs. It consists of an instrument which modulates or sweeps an oscillator frequency over a prescribed frequency range and which utilizes the change in the load on the tank circuit of the oscillator to change the operating mode of said oscillator to indicate the plating thickness. The system is so designed that this load change causes the oscillator to commence or cease oscillating, depending

upon whether the frequency is being increased or decreased. The resultant signal provided by starting or stopping of the oscillator is applied to a cathode ray oscilloscope and the change from one condition to another produces a vertical mark or pip on the horizontal trace. The cathode ray tube may be calibrated to read thickness of a particular installation directly.

Referring to Figure 1, the graph therein shows the fundamental principle for obtaining the oscillatory-non-oscillatory conditions of a system including an oscillator and a tank circuit having a load. The curve G_1 represents the change in conductance in the tank circuit or load circuit as the frequency increases. It is noted that this curve falls off as the frequency increases; in other words, the conductance decreases as the frequency increases. On the other hand, the curve G_2 represents the change in conductance in the oscillator circuit as the frequency increases. G_2 shows an increase in conductance. The two curves cross at point A. At any frequency above A the negative conductance of the reactance oscillator exceeds the conductance of the tank circuit and the former will continue to oscillate, feeding the load. This is indicated by the defining words of Figure 1. At point A the two conductances are equal; however, below A the load conductance exceeds that of the reactance oscillator, which condition causes the oscillator to cease oscillating. This change in operating mode occurs at a frequency slightly below the critical frequency A.

The formula for G_1 is:

$$G_1 \simeq k_3 \frac{\sqrt{\mu\sigma}}{\omega^{3/2}}$$

where:

k_3=a constant
μ=the permeability of the material
σ=conductivity of material
ω=frequency

Therefore, the conductance of the tank circuit varies directly with a variation in the permeability of the material and inversely as the frequency.

On the other hand:

$$g_2 \simeq k_1 + k_2\omega^2$$

where:

k_1=a constant
k_2=a constant
ω=the frequency

G_2 is therefore directly proportional to the square of the frequency. It is not affected by the material of the load.

For a particular installation the critical frequency A may therefore be determined by use of the above equations.

Since, from the equation for G_1, it is clear that the product $\mu\sigma$ defines the horizontal position of the graph with respect to the axis of the G_1 curve, Figure 2 illustrates a family of curves for G_1 which result as the material under study varies in its characteristics. Each curve C intersects curve D for G_2 at a different point of frequency, F_1, F_2, F_3, F_4, F_5, F_6, and F_7, thus indicating the critical frequency at which a reactance oscillator will stop when used with particular materials.

With this background, Figure 3 illustrates by block diagram the essential elements of a measuring system embodying our invention. The oscillator **2** is designed to oscillate over a band of frequencies determined as above described; for example, let it be assumed to be a band around 750 kc. A modulator **4** is connected to said oscillator to modulate the frequency thereof a given amount on both sides of the reference frequency. This is with the assumption that the material to be measured is in the neighborhood of .001 of an inch thick and is copper on steel. The oscillator tank circuit is shown as including a condenser **6** and an inductance **8**. The tank circuit is connected to a buffer amplifier **10** through

line **12**. The probing coil **14** is connected to the tank circuit through lines **16** and **20** and coupling coil **22** in inductive relation with tank load coil **8**. The output of the amplifier **10** is fed to a detector and differentiator **24** which in turn is connected to the oscilloscope **26**. As the modulator sweeps the oscillator over the band of frequencies which includes a critical frequency of an estimated dimension in a known material, a signal will be developed in the amplifier due to the oscillator stopping or starting. The signal will be amplified and detected and applied to the oscilloscope **26** to give a vertical mark or pip. The repetitive modulation of the oscillator with the synchronized sweep of the oscilloscope causes a continuous trace on the face of the oscilloscope and the horizontal position of the pip indicates the thickness, and the distance may be calibrated.

The constants of the oscillator **2** are chosen so that it is capable of oscillating at frequencies both above and below that frequency that causes a depth of penetration equivalent to the thickness of the coating or plating which it is desired to measure. The modulator **4** is connected to sweep the oscillator over this band of frequencies. The tank circuit of the oscillator, which, it will be recalled, is that circuit in which the load is changed by the penetration of the induced current into the material being measured, includes the inductance **8**, to which is coupled the probing coil **14** by a low impendance coupling through coil **22**. As the frequency of the oscillator decreases, the current penetration into the coating of the part induced by the coil **14** increases, and when it penetrates through the thickness of the coating, the load on the coil and the tank circuit connected thereto changes and the oscillator will stop. This change in the oscillator output produces a pulse which is applied to the buffer amplifier **10** and the detector **24**, the output of the latter being applied directly to the vertical plates of the oscilloscope to produce an indicating pip on the screen. The oscilloscope sweep is synchronized with the modulator so that one horizontal sweep trace is produced for each cycle of modulation of the modulator. Thus repetitive traces are produced with a vertical pip located along the horizontal trace whose position indicates the thickness of the coating.

Rather than to have to provide different oscillators for different thickness ranges of material or for different materials of the same thickness, a single oscillator tube may be provided with a plurality of reactance oscillator circuits and a plurality of matching tank load circuits having different values so that several ranges may be supplied by merely simultaneously switching the two. Figure 4 illustrates such a system. There is shown therein a testing device having five different ranges, and therefore capable of being used for either differing materials or differing thickness ranges. The reactance oscillator tube **30** has its reactance input circuit defined by any one of a plurality of inductance coils **32**, **34**, **36**, **38** and **40**, connected to stationary switch contacts **42**, **44**, **46**, **48** and **50** respectively. The opposite ends of each of the inductance coils **32** through **40** are commonly connected to line **52** which is connected to ground through condenser **54**. A movable switch arm **56**, which may be moved into contact with any one of the stationary contacts **42** through **50** is connected through a dropping resistor **58** to the control grid **60** of tube **30**.

The cathode **62** of the tube **30** is directly connected to the suppressor grid **64** of the tube, and likewise through biasing resistor **66** to ground. The cathode is also connected through a further resistor **68** in series with a filtering condenser **70** and two series resistances **72** and **74** to ground. Common line **52** is connected through a biasing battery **76** to a movable switch arm **78** and a shunting resistor **80** is connected around the biasing battery. The biasing battery **76** is supplied to maintain the grid negative with respect to the cathode under operating conditions. Movable arm **78** is adapted to engage a series of stationary

contacts **81, 82, 84, 86** and **88**, each of which is connected to a variable tap **90** on a resistance **92** in order to provide differing amounts of modulating signal. The upper end of each of the resistors **92** is commonly connected to line **94** which extends to the sweep generator and is the line upon which the modulating signal is applied. Conversely, the opposite end of each of the resistances **92** is commonly connected to a line **96**, which line is connected to ground through grid return resistor **98**.

The plate **100** of the oscillator tube **30** is connected through line **102** with movable switch arm **104** which is adapted to engage a plurality of stationary contacts **106, 108, 110, 112** and **114**. To these taps are connected the various tank or load circuits adapted to be coupled to the probing coil. Thus a resistance **116** and an industance **118** are connected in series between contact **106** and line **120**. A radio frequency bypass condenser **122** is connected between line **120** at the first station and ground. Coil **118**, therefore, is the tank inductance for the first section. Inductively coupled to coil **118** is a low impedance coil **124**, one end of which is grounded and the opposite end of which is connected through line **126** to sationary contact **128** on a further multiple contact switch. The movable switch arm **130** is adapted to move over a plurality of stationary contacts **128, 132, 134, 136** and **138**, which are each in circuit with various tank circuits of the oscillator. The arm **130** is connected through line **140** with the center conductor of the plug-in receptacle **142**. A probe coil **144** is energized by the oscillatory signal on line **140** through plug **146**, which mates with the receptacle **142**. The line **140** is enclosed in a grounded shield **148**.

The second tank circuit, the components of which have different values from the first, includes a resistance **150**, transformer coil **152**, and radio frequency bypass condenser **154**, connected in series between switch contact **108** and ground. A coupling coil **156** is mounted on the same core as coil **152** and is connected to stationary contact **132** of the selector switch **130**. Similar tank and coupling circuits of differing values for different materials or dimensional ranges are similarly connected to switch contacts **110, 112** and **114**, and to contacts **134, 136** and **138**. These tank circuits are identified generally as **158, 160** and **162** respectively. While a plurality of condensers such as **122** and **154** are shown in spaced relation between different portions of line **120** and ground, a single condenser of the proper size may be substituted if desired.

An oscilloscope and power supply therefor are identified by the block diagram **164**. Line **120** is connected to the power supply section of the oscilloscope to provide a voltage therefor. Screen grid **166** of tube **30** is connected to line **120**. A variable tap **168**, movable over resistance **74**, is connected through resistor **170** to line **172** which in turn is connected to the vertical amplifier of the oscilloscope at the terminal marked V on the oscilloscope housing. Through this line the indicating signal is applied and it provides the vertical indication on the trace for measurement. Movement of the tap **168** varies the amplitude of the signal applied to the oscilloscope and therefore regulates the sensitivity of the system. By taking the signal off the oscillator in this manner, the oscillator plate current is isolated from the potentiometer formed of resistors **72** and **74** and a more regulated signal is obtained.

A modulating sawtooth wave is generated to sweep the oscillator over a desired band of frequencies. Frequency shift of the oscillator can be affected electronically by changing the potential of control grid **60**. This changes the trans-conductance g_m of the tube which changes the effective value of the grid-to-plate capacitance. In the analysis of the reactance tube, it is found that the grid-to-plate capacitance (illustratively shown in dotted lines in tube **30**) is one of the elements which controls the resonant frequency of the oscillator. The means for generating the sawtooth modulating wave is also used as a sweep generator for the synchronized horizontal trace of the oscilloscope. This generator includes two tubes, **174** and **176**.

The first tube is a duo-triode having plates **178** and **180**, grids **182** and **184**, and cathodes **186** and **190**. A separate power supply section **192** is provided for this generator section, the output of which is connected to supply line **194**. The plates **178** and **180** are connected to the power supply line **194** through load resistors **196** and **198** respectively. A potential divider consisting of resistors **200** and **202** in series is connected between line **194** and ground. A condenser **204** is connected between plate **178** and a point intermediate resistors **202** and **200**. Grid **184** of the second triode section is connected to the same point. Cathode **190** is connected to ground through biasing resistor **206**, shunted by condenser **208**. In similar manner cathode **186** is connected to ground through biasing resistor **210** shunted by condenser **212**. Control grid **182** of the first section is connected to the filament supply line **214** which may be connected to any suitable source of alternating current such for example as 60 cycle commercial power. This section forms a square wave pulse generator oscillating at the frequency of the filament supply current.

The square wave output of the pulse generator arriving from plate **180** is differentiated by the R-C network made up of resistance **220** and capacitance **216**. Thus on line **218** there appears a series of alternate positive and negative spikes representing respectively the differentiated leading and lagging edges of the square wave. By placing rectifier **222** across resistance **220** with proper polarity, the negative voltage spike can be shorted out, leaving only positive voltage pulses on the line **218**. These voltage pulses are applied through condenser **224** to control grid **226** of gas tube **176**, which is permanently biased to cutoff through resistor **230** and line **228** coming from the power supply in the oscilloscope, indicated as minus (—). Condenser **224** prevents the permanent bias on grid **226** from being short circuited through rectifier **222** as it blocks D.C. voltage. The biasing voltage on line **228** may, for example, be —40 volts, which prevents the tube **176** from conducting in the absence of a positive pulse on line **218**.

The power supply line **194** is likewise connected to a resistance **232**, the other terminal of which is connected by line **234** with the plate **236** of the tube **176**, with one terminal of condenser **238**, and to an intermediate point between resistors **240** and **242** which form part of a voltage divider. A resistor **244** is connected in series between resistor **242** and ground, and completes the voltage divider connected between line **94** and ground. As previously mentioned, this generator section provides a sawtooth wave on line **94** to modulate the oscillator over a desired band and also to produce a synchronizing pulse on line **246** which extends from a point between resistors **242** and **244** to the synchronizing sweep control H of the oscilloscope. In providing the sawtooth wave to the potential divider, the condenser **238**, whose remaining terminal is grounded, is alternately charged and discharged. When it is in a discharged state, it is charged through current flow from the power line **194** through limiting resistance **232**. When it reaches a point near full charge, the potential on the control grid **226**, applied by a pulse from the pulse generator **174**, will cause the thyratron tube **176** to conduct. Up to the point of tube conduction the voltage on the voltage divider **240, 242, 244** gradually increases to a maximum. When the tube conducts, the condenser **238** quickly discharges therethrough to ground and the voltage on the potential divider drops sharply. The next half cycle causes the thyratron to cut off due to the high negative bias on line **228** and the condenser **238** again charges and the voltage potential across the divider increases. This operation causes an alternate voltage increase and decrease producing a sawtooth wave form of voltage on line **94** at the pulse frequency which is that of the supply voltage.

In operating this equipment, it is desired to point out that there are a plurality of control switches, all of which are mechanically interconnected so that they are

simultaneously moved to different switch points and thus provide for operation on different materials or over different dimensions. This is shown by the dotted lines interconnecting switch arms 56, 78, 104 and 130.

Assuming that it is desired to operate the device on the frequency defining and tank circuits connected to the second set of terminals, the apparatus is adjusted as follows: the probe **144** is placed on the surface to be inspected and whose plated thickness dimension is known. The core C of the grid inductance 34 is adjusted until the oscillator ceases to oscillate within the range swept by the modulator. At this point it should be pointed out that in this case the frequency is swept from a high frequency to a lower one, and therefore the oscillator proceeds from an oscillatory condition at the high frequency end to a non-oscillatory at the lower frequency. Having adjusted the oscillator so that it sweeps a band within which the condition of the oscillator changes for the given laminar thickness, the operator next selects a second sample of laminar material which is known to have a greater thickness, the two samples providing tolerance limits, and again adjusts core C with the device operating until a signal is obtained at this second thickness, the signal of course being produced by the oscillator becoming non-oscillatory from an oscillatory state. The operator then returns to the first sample to see if it is still within the range of modulation of the oscillator at this new core setting. If it is, then both limits of a laminar thickness which is satisfactory are within the range of the instrument and it is now correctly calibrated for use on these particular materials for testing the given thicknesses. If upon returning to the first sample it is found that a signal is not obtainable, then the adjustable tap **90** on the second potentiometer connected to switch point **82** is adjusted to give a higher amplitude to the sawtooth modulating wave to widen the frequency band until both signals appear within the modulating range. When that occurs, the device is ready for operation and the operator merely applies the probe to the surface of samples being tested for laminar thickness, and if a signal is obtained on each, as indicated by the oscilloscope trace, then the laminar thickness is within proper limits.

The oscillator changing from a non-oscillatory to an oscillating condition, or vice versa, produces a change in the voltage across resistor 74, which voltage is applied to the vertical plates of the oscilloscope, and therefore produces a step wave when the oscilloscope is synchronized with the synchronous generator voltage tapped off between resistors **242** and **244**. If the size of the resultant signal on the oscilloscope is too small, tap **168** may be adjusted to increase the sensitivity of response and obtain a larger and more easily read signal. The face of the oscilloscope may be calibrated in thickness from empirically determining the thicknesses being tested. In like manner the ganged control switches may be moved to other positions and the associated cores C adjusted for other materials and for other dimensional ranges, and the device therefore can be set up for a plurality of different situations and can quickly be changed from one to another for any one of the fixed materials and/or dimensional ranges.

The probe itself is shown in two forms, the first being illustrated by Figures 5 and 6, and a second modified form in Figures 7 and 8. Since relatively high frequencies are used, it is necessary to shield the inductance winding in order to obtain satisfactory readings. That form shown in Figures 5 and 6 includes a main shield **250** which is made of a material having good electrical conducting quality such for example as copper. This housing or shield includes an opening **252** therethrough of one diameter connected to a larger bore 254 adjacent the lower face. Into this opening the main probe assembly is inserted and held tightly therein by a set screw **256**. The inductance support per se includes a body portion **258** which is formed of an insulating material such as polystyrene. A central bore **260** is provided in the body 258 through which connections to the coil may be made. A coupling **262** is rigidly secured to the upper surface of the body **258** which proceeds through the opening **252** in the housing **250**, and is threaded to be coupled to the conductive shielded line **140** coming from the tank circuits. The central bore **260** is connected to a diagonal channel **264** which extends to an annular cavity 266. A wire affixed to the center conductor of the coupling 262 threads through channels **260** and **264** and is wound a predetermined number of turns around the insulating body **258** as shown at **265**. This, then, is the actual probing inductance. The free end of the wire is brought out through opening **267** in a polystyrene shield 268 and soldered to the housing **250**, which, through the outer diameter of coupling **262** and the shield of the interconnecting cable between **262** and receptacle **142** is returned to ground and completes the electrical circuit. The main housing **250** has an indexing lip **251** and is adapted to be used when applying the probe to curved bearing surfaces.

The second form of probe coil, which is shown in Figures 7 and 8, consists of the same coil support **258** around the lower annular periphery of which the test coil assembly **265** is mounted, but in this instance the shield or cover assumes the form of an annular cap **270** which fits over the top of the member **258** and is secured thereto through a set screw **272** which extends through the shoulder of the cap and into the body **258**. This shield is also of good conductivity material and may be, for example, copper. Body **258** is as before formed of an insulating material such as polystyrene, and the coil assembly **265** may be molded in place by filling the cavity with insulating material after the wires are wound around the lower end of the body **258**. As before, the electrical connections to the coil may be made through duct **264** and bore **260**. This type of mounting for the probe coil is to be used on flat surfaces. Other shapes of housing may be used to apply the probe coil at right angles to the surface to be tested.

We claim:

1. In measuring means, an oscillator including an electron device having a control electrode and an input circuit connected to the control electrode and an output circuit, said oscillator being tunable over a frequency range by varying the voltage on the control electrode, inductive means connected to the output circuit including a test inductance in which the loading may be changed, means connected to the input circuit for repetitively cyclically changing the voltage on the control electrode for modulating the oscillator over a prescribed frequency band, and adjustable means in said input circuit for varying the band of modulation so that the oscillator will change from oscillatory to non-oscillatory condition within a range of modulation at prescribed loading changes in the test inductance.

2. In measuring means, an oscillator including an electron device having a control electrode and an input circuit connected to the control electrode and an output circuit, said oscillator being tunable over a frequency range by varying the voltage on the control electrode, means for generating a sawtooth wave form of voltage connected to the input circuit to vary the oscillator frequency, a tank circuit including inductance means connected in the output circuit, a probing coil inductively coupled to the inductance in the tank circuit and adapted to be associated with a laminar device to be tested, the inductance of said laminar device as reflected in the probe coil varying the loading in the tank circuit and causing the oscillator to change from an oscillatory to a non-oscillatory condition.

3. In measuring means, an oscillator including an electron device having a control electrode and an input circuit connected to the control electrode and output circuit, said oscillator being tunable over a frequency

range by varying the voltage on the control electrode, means for generating a sawtooth wave form of voltage connected to the input circuit to vary the frequency of the oscillator, means in this connection to adjust the amplitude of the sawtooth voltage to adjust the frequency range, a tank circuit connected to the oscillator output, an inductance probing coil inductively coupled to the tank circuit and adapted to be placed in juxtaposition to the surface of a laminated body so that as the frequency of the oscillator varies over a band as prescribed by the modulator, the penetration of the current induced in the laminated body will vary, changing the loading on the tank circuit, and causing the oscillator to change from an oscillatory to a non-oscillatory state.

4. In measuring means, an oscillator including an electron device having a control electrode and an input circuit connected to the control electrode and an output circuit, said oscillator being tunable over a frequency range by varying the voltage on the control electrode, means for generating a sawtooth wave form of voltage connected to the input circuit to vary the frequency of the oscillator, means in this connection to adjust the amplitude of the sawtooth voltage to adjust the frequency range, a tank circuit connected to the oscillator output, an inductance probing coil inductively coupled to the tank circuit and adapted to be placed in juxtaposition to the surface of a laminated body so that as the frequency of the oscillator varies over a band as prescribed by the modulator, the penetration of the current induced in the laminated body will vary, changing the loading on the tank circuit as the laminar boundary is reached, and causing the oscillator to change from an oscillatory to a non-oscillatory state at that point, an oscilloscope, and means for connecting the oscillator output to the oscilloscope to indicate the condition thereof as an indication of the penetration of induced current to the lamination boundary.

5. In measuring means, an oscillator including an electron device having a control electrode and an input circuit connected to the control electrode and an output circuit, said oscillator being tunable over a frequency range by varying the voltage on the control electrode, means for generating a sawtooth wave form of voltage connected to the input circuit to vary the frequency of the oscillator, means in this connection to adjust the amplitude of the sawtooth voltage to adjust the frequency range, a tank circuit connected to the oscillator output, an inductance probing coil inductively coupled to the tank circuit and adapted to be placed in juxtaposition to the surface of a laminated body so that as the frequency of the oscillator varies over a range as prescribed by the modulator, the penetration of the current induced in the laminated body will vary, changing the loading on the tank circuit at a laminar boundary, and cause the oscillator to change from an oscillatory to a non-oscillatory state at that point, an oscilloscope, means for connecting the oscillator output to the oscilloscope to indicate the condition thereof as an indication of the penetration of induced current in the laminated body to a boundary, and means interconnecting the means for generating the sawtooth wave and the synchronizing circuit of the oscilloscope to control the horizontal sweep in synchronism with the modulation of the oscillator.

6. In measuring means, an oscillator including an electron device having a control electrode and an input circuit connected to the control electrode and an output circuit, said oscillator being tunable over a frequency range by varying the voltage on the control electrode, means for generating a sawtooth wave form of voltage connected to the input circuit to vary the frequency of the oscillator, means in this connection to adjust the amplitude of the sawtooth voltage to adjust the frequency range, a tank circuit connected to the oscillator output, an inductance probing coil inductively coupled to the tank circuit and adapted to be placed in juxtaposition to the surface of a laminated body so that as the frequency of the oscillator varies over a range as prescribed by the modulator, the penetration of the current induced in the laminated body will vary, changing the loading on the tank circuit at a laminar boundary, and causing the oscillator to change from an oscillatory to a non-oscillatory state at that point, and indicating means connected to the oscillator and to the means for generating the sawtooth wave form to indicate the change from oscillatory to non-oscillatory state synchronized with the frequency scanning.

7. Measuring apparatus of the character described, including, means for generating electromagnetic waves which may be tuned by varying the input voltage, modulating means connected to said wave generating means to vary the input voltage for cyclically varying the frequency of said generated waves over a predetermined band, an output circuit connected to said wave generating means, said circuit including an output impedance, a test head including a test impedance adapted to be placed closely adjacent a laminar part to be tested, said test impedance being coupled to the output impedance to load said output impedance and change the mode of operation of the wave generating means as the current induced in said laminar part changes and extends into different strata thereof.

8. Measuring apparatus of the character described, including, means for generating electromagnetic waves which may be tuned by varying the input voltage, modulating means connected to said wave generating means to vary the input voltage for cyclically varying the frequency of said generated waves over a predetermined band, an output circuit connected to said wave generating means including an output inductance, a test head including a test inductance adapted to be placed closely adjacent a laminar part to be tested, said test inductance being coupled to the output inductance to load said inductance and change the load on the wave generating means as the current induced in said laminar part changes and extends into different strata thereof.

9. In measuring means for determining the thickness of laminar layers, an oscillator whose frequency may be varied by changing the input voltage having a plurality of tunable input circuits and a plurality of tunable output circuits, a source of sawtooth wave voltage, a plurality of adjustable potentiometer means individually connectable to each tunable input circuit and to the source of sawtooth wave voltage to adjust the range, a probing inductance adapted to be placed adjacent a laminated body to measure the lamina thickness selectively connectable with each tunable output circuit and common ganged switching means in the connections between the tunable input circuits and the oscillator, the tunable output circuits and the oscillator, the adjustable potentiometer means and the tunable input circuits and the probing inductance and the tunable output circuits so that the device may be switched to accommodate different materials and thickness ranges.

10. In measuring means for determining the thickness of laminar layers, an oscillator whose frequency may be varied by changing the input voltage having a plurality of tunable input circuits and a plurality of tunable output circuits, a source of sawtooth wave voltage, a plurality of adjustable potentiometer means individually connectable to each tunable input circuit and to the source of sawtooth wave voltage to adjust the range, a probing inductance adapted to be placed adjacent a laminated body to measure the lamina thickness selectively connectable with each tunable output circuit, common ganged switching means in the connections between the tunable input circuits and the oscillator, the tunable output circuits and the oscillator, the adjustable potentiometer means and the tunable input circuits and the probing inductance and the tunable output circuits so that the device may be switched to accommodate dif-

ferent materials and thickness ranges, oscilloscope means having vertical and horizontal deflecting means, and conductor means connecting the oscillator output with the vertical deflecting means and the source of sawtooth wave voltage to the horizontal deflecting means to indicate the laminar thickness.

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